VEGETATION OF TWO SOUTHEASTERN ARIZONA DESERT MARSHES

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ABSTRACT

Detrended Canonical Correspondence Analysis (DCCA) was used to identify and classify groups of vascular plants in two desert marshes, the Babocomari Ciénega and the Canelo Hills Ciénega, in southeastern Arizona. Species composition and the effect of several environmental factors on species distributions were identified by direct gradient analysis using DCCA. The species distributions were best correlated with environmental factors related to the moisture regime (Babocomari Ciénega) and to the amount of canopy cover (Canelo Hills Ciénega). They were least correlated with disturbance and bare ground at both the Babocomari Ciénega and the Canelo Hills Ciénega. Based on the selected environmental factors, three main species groups were identified at the Babocomari Ciénega and at the Canelo Hills Ciénega. *Rorippa nasturtium-aquaticum* and *Berula erecta* dominate the stream area where water is deepest and flowing and canopy cover is the greatest. *Eleocharis macrostachya* and *Muhlenbergia asperifolia* dominate the ciénega area where water is shallow and standing. *Muhlenbergia rigens* and *Ambrosia trifida* dominate the periphery where there is no standing water and soils are dry. Differences in species composition within these areas between ciénegas may reflect differences due to land use history.

RESUMEN

Para identificar y clasificar grupos de plantas vasculares en dos ciénegas desérticas del sureste del Arizona, la Babocomari Ciénega y la Canelo Hills Ciénega, se usó la técnica de ordenación "Detrended Canonical Correspondence Analysis" (DCCA). La composición florística y el efecto de varios factores ambientales en la distribución de las especies se identificaron con un análisis directo de gradiente usando DCCA. La distribución de las especies estuvo mejor correlacionada con factores ambientales asociados con el régimen de humedad (Babocomari Ciénega) y con la coberatura vegetal (Canelo Hills Ciénega); pero menos correlacionada con las perturbaciones y la proporción de suelo desnudo. Con base en los factores ambientales selectos, se identificaron tres grupos principales de especies en la Babocomari Ciénega y la Canelo Hills Ciénega. *Rorippa nasturtium-aquaticum* y *Berula erecta* dominaron en la zona de corriente, donde el agua fluye y es más profunda. *Eleocharis macrostachya* y *Muhlenbergia asperifolia* dominaron en la zona ciénega, donde el agua es somera y quieta. *Muhlenbergia rigens* y *Ambrosia trifida* dominaron en la periferia donde no hay agua y el suelo está seco. Las diferencias en composición florística de las ciénegas dentro de estas zonas puede reflejar diferencias históricas en el uso de la tierra.

Ciénegas are unique freshwater wetlands found in semiarid grasslands of the southwestern United States and northern Mexico. Located along streams or near freshwater springs, wetland conditions are maintained by a permanent water supply, and soil chemistry is

controlled by permanently saturated conditions (Hendrickson and Minckley 1985). Although riparian woody species, such as *Populus fremontii* and *Salix gooddingii,* identify the location of ciénegas in grasslands, much of the surface area in ciénegas is comprised of herbaceous and graminoid species.

This vegetation often appears to be zoned in linear bands parallel to the stream channel. Several descriptions of ciénega vegetation suggest that the local moisture conditions may influence species composition and distribution, but plant species composition may also be determined by other biotic and abiotic factors (Hendrickson and Minckley 1985; Marrs-Smith 1983; Yatskievych and Jenkins 1981). In addition, vegetation patterns may also reflect the disturbance and land use history of the ciénega.

Most ciénegas have been used by humans for at least the last 500 years (Bahre 1977). Beginning with the Native Americans, ciénegas have been used for agriculture since the 1400's (Di Peso 1953) and for cattle ranching since the arrival of the Spanish colonists in the 1500's (Bahre 1977). Today, of 15 extant ciénegas in southwestern New Mexico and southeastern Arizona, only five are protected from cattle grazing and farming (Hendrickson and Minckley 1985). Natural disturbances that affect the local hydrological regime, such as periodic droughts or floods (Sellers et al. 1985) and prolonged freezing temperatures (Bowers 1981) may also influence species distribution patterns. Most ciénegas are located near stream headwaters, and dams that are built downstream to check erosion do little to control flooding (Hendrickson and Minckley 1985).

The purpose of my research was to describe the plant species composition of two ciénegas with differing land use histories, and to relate the species distribution patterns to several environmental factors. Understanding ciénega vegetation is essential for the successful management and preservation of this rare ecosystem.

Study Site and Methods

Site location. Both the Babocomari Ciénega and the Canelo Hills Ciénega are located in the high desert grasslands of the San Pedro River Basin, Arizona. The ciénegas share a semiarid climate with a bimodal pattern of precipitation averaging 41 cm annually, falling as winter and summer rain. Temperatures recorded within two kilometers of each site show that the highest average temperature (24°C) occurs in June and the lowest average temperature (6°C) occurs in December (Sellers et al. 1985).

Five desert mountain ranges encircle the basin: Santa Rita Mountains, Canelo Hills, Huachuca Mountains, Patagonia Mountains, and Mustang Mountains (Vice 1974; Feth 1947). Runoff from these

mountains, in addition to precipitation, provides water to the ciénegas.

At an elevation of 1365 m, the Babocomari Ciénega is part of the San Ignacio del Babocomari Land Grant in Santa Cruz and Cochise Counties, Arizona. The Babocomari Ciénega covers 62.5 ha of the 13,600-ha Babocomari Ranch in the Babocomari River basin at the base of the Mustang Mountains. Many small stream channels dissect the basin and converge into one stream channel near a dam built in the 1930's.

The Canelo Hills Ciénega, formerly called Knipe Ciénega, is located at 1485 m on O'Donnell Creek, a tributary of the Babocomari River. It is included in the Nature Conservancy Canelo Hills Ciénega Preserve in Santa Cruz County, Arizona. The Canelo Hills Ciénega covers 12.5 ha on the preserve and approximately 25 ha of adjacent property. The water regime differs slightly from that at the Babocomari Ciénega, as it also includes inputs from two nearby springs. There are fewer stream channels than at the Babocomari Ciénega, and these converge at a dam built in 1969.

Except for the last 20 years, the land use history has been similar at the Babocomari Ciénega and the Canelo Hills Ciénega. Both have been used either for farming or ranching by Native Americans, Spanish colonists and missionaries, army troops, homesteaders, and cattle ranchers. Both experienced drought in the 1890's and in the 1950's and prolonged freezing temperatures in 1975. Flood records are unavailable for the Babocomari Ciénega, but the Nature Conservancy records indicate that the last major flood at the Canelo Hills Ciénega occurred in 1969 before the dam was installed. Aside from major flood events, there is undoubtedly annual variation and fluctuation in the water level depending on precipitation and runoff input. The Babocomari Ciénega has been an operating cattle ranch since the 1930's and remains so, whereas the Canelo Hills Ciénega was grazed prior to its purchase by the Nature Conservancy in 1969. Preserve managers have burned the Canelo Hills Ciénega several times since 1969 in order to simulate a natural fire cycle.

Vegetation sampling. In June and July 1985, the vegetation at the Babocomari Ciénega was identified and recorded along 16, 350-m north–south, line transects (Greig-Smith 1983) 100 m apart. Supplementing these preliminary measurements with aerial photographs (taken in 1985) and visual reconnaissance, four main vegetation zones were observed along a moisture gradient and were classified as: (1) grassland, (2) high ciénega, (3) low ciénega, and (4) stream.

The vegetation was sampled at the Babocomari Ciénega and the Canelo Hills Ciénega using this classification in June and July 1986. By randomly sampling the vegetation within these areas, a large data set that was representative of ciénega vegetation was obtained. In

each ciénega, 79 quadrats were sampled: 20 quadrats were placed randomly in each of the high ciénega, low ciénega, and grassland areas and 19 quadrats were randomly placed in the stream area. Species abundance was estimated within 1-m² quadrat frames that were divided into 100 10-cm² squares. The number of squares in which a species occurred was used as an estimate of abundance. Voucher specimens were verified by Dr. William A. Weber and were deposited at the University of Colorado Herbarium (COLO). A complete list of the 135 species collected is in Fernald (1987). Nomenclature follows Lehr (1978) with verifications by Dr. Weber.

Environment sampling. In 1986, ranked values for 12 environmental factors thought to influence vegetation patterns were recorded for each 1-m² quadrat in both ciénegas. The 12 factors were: (1) disturbance, (2) stability, (3) site moisture, (4) soil moisture, (5) water depth, (6) water flow velocity, (7) water clarity, (8) slope, (9) canopy cover, (10) percentage bare ground, (11) percentage litter cover, (12) percentage grass and herbaceous plant cover (for a complete explanation of descriptors see Fernald 1987). Elevation was determined from United States Geological Survey 7.5″ topographical maps for the O'Donnell Canyon and Mustang Mountains quadrangles.

Data analysis. Analyses of 1985 transect data considered only species cover at the Babocomari Ciénega. Analyses of 1986 data used only species that occurred in 10 or more quadrats at the Babocomari Ciénega and the Canelo Hills Ciénega. Detrended Canonical Correspondence (DCCA) or direct gradient analysis (ter Braak 1987; Jongman et al. 1987) was used to ordinate vegetation with the environmental variables. Analysis with Detrended Correspondence Analysis (DCA), an indirect gradient analysis, was also performed to examine species composition without the constraints imposed by the environmental factors. DCA results were similar to DCCA and will not be discussed here. In addition, when environmental factors have been measured, DCCA is thought to be more effective than the traditional indirect method of DCA (ter Braak and Prentice 1988). The DCCA analyses were performed with the Canonical Community Ordination program (CANOCO) (ter Braak 1987). Detrending-by-polynomials was used, because it is considered to be a stable means of reducing polynomial distortion of the first DCCA axis onto subsequent axes (ter Braak 1987). However, due to the lack of an arch effect (Gauch 1982) with respect to the second DCCA axis no detrending was performed on this axis for either ciénega.

RESULTS

Generally, the vegetation at the Babocomari Ciénega and at the Canelo Hills Ciénega was distributed along an elevation-moisture

gradient. In both ciénegas, the stream channel could be readily iden-
tified by the tall-statured cottonwood and willow riparian species.
Immediately adjacent to the stream channel was an expansive, flat
ciénega area that was dominated by various rush and sedge species.
A mix of invasive herbaceous species was gradually replaced by
native grass species in the drier areas above the ciénega. The mesic
vegetation of the ciénegas was easily distinguished from the sur-
rounding oak-savanna vegetation that defines the semiarid grass-
lands of southeastern Arizona.

The transect data showed that two species, *Eleocharis macro-
stachya* and *Carex praegracilis,* covered about 29% at the Baboco-
mari Ciénega. Other monocotyledonous species, primarily grasses,
sedges, and rushes, covered 57%, and herbaceous dicotyledonous
species covered 14%. These data were not collected at the Canelo
Hills Ciénega.

Of the 30 species analyzed, 27 occurred at the Babocomari Ciénega
and 28 occurred at the Canelo Hills Ciénega. *Anemopsis californica*
and *Muhlenbergia asperifolia* were restricted to the Babocomari Cié-
nega and *Scirpus americana* and *Apocynum suksdorfii* were restricted
to the Canelo Hills Ciénega, but all other species used in the analyses
were found in both locations.

DCCA results showed that for the Babocomari Ciénega primary
environmental factors that may have explained the first axis (eigen-
value [e] = 0.72) and the second axis (e = 0.42) were related to the
moisture gradient. Canonical correlation coefficients (c) for site
moisture and soil moisture with the first axis were 0.9140 and 0.8876
respectively. The first axis separated species in group I (dry, periph-
eral sites) from species in groups II and III (wet sites, stream and
ciénega) (Fig. 1). Although these variables appeared to be related,
the inflation factor, a descriptor that estimates the relationship be-
tween the environmental variables, was low (<50 [ter Braak 1987]),
and both of these variables were used to interpret the first axis. The
second axis was explained primarily by water clarity (c = 0.4040),
which roughly estimated the amount of turbidity. This axis separated
species in group II (high turbidity) from groups I and III (low or no
turbidity) (Fig. 1). The third axis (e = 0.24) and fourth axis (e =
0.19) were not strong enough to explain much of the variation, but
are illustrated in Fernald (1987).

DCCA results showed that for the Canelo Hills Ciénega the pri-
mary environmental factors that were used to explain the first axis
(e = 0.67) were percentage slope and percentage litter cover and for
the second axis (e = 0.57) percentage canopy cover. Canonical cor-
relation coefficients for the first axis with slope and litter were 0.4869
and 0.6213 respectively. The first axis separated species where the
topography was essentially level in the ciénega (group I) and the
stream (group II) from grass species along the slope of the periphery
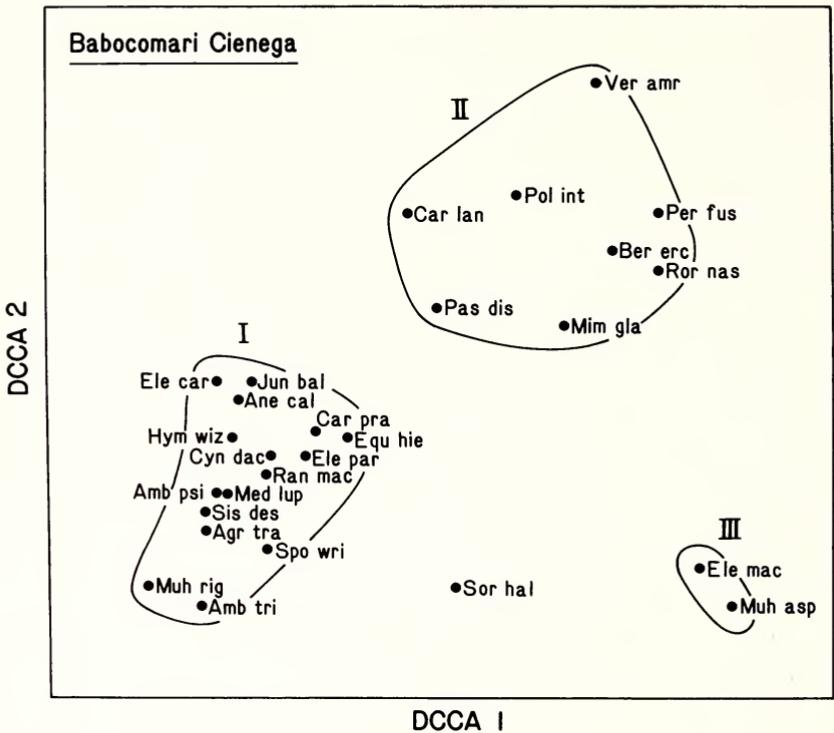(group III) (Fig. 2). The second axis may be explained primarily by

Fig. 1. Detrended canonical correspondence analysis (DCCA) ordination of species-by-environment variables for the Babocomari Ciénega (summer 1986). Species groups generally represent the following locations along the moisture gradient: I = dry, peripheral sites, II = wet, stream sites, and III = wet, ciénega sites. Names for species' abbreviations are listed in Table 1.

canopy cover (c = −0.7938) which differentiates between plots under trees and in the open. This axis separated species in group II (100% canopy) from species in group I (50% canopy) and from species in group III (0% canopy) (Fig. 2). The third axis (e = 0.32) and the fourth axis (e = 0.30) were not strong enough to explain much of the variation, but are illustrated in Fernald (1987).

Generally, several plant species may be used to identify the vegetation-by-environment groups that were separated by DCCA. *Rorippa nasturtium-aquaticum* and *Berula erecta* dominated the stream area that was characterized by deep, flowing water, saturated soils, and nearly complete canopy cover. *Eleocharis macrostachya* and *Muhlenbergia asperifolia* dominated the ciénega area that was characterized by shallow, standing water, intermittently saturated soils, and sparse, patchy canopy cover. *Muhlenbergia rigens* and *Ambrosia*
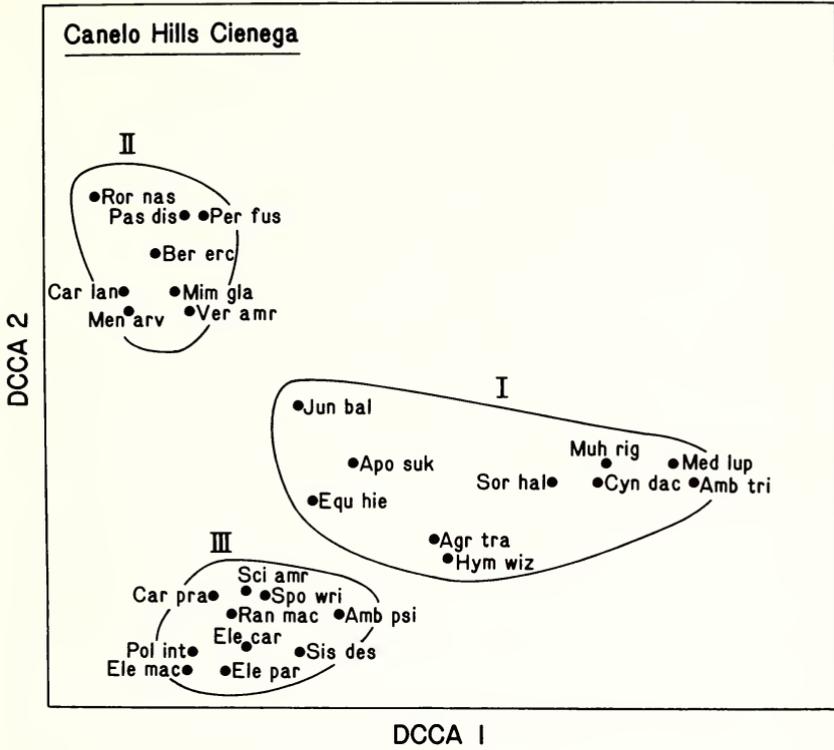
Canelo Hills Cienega

II
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Ele mac• •Ele par •Sis des

DCCA 2
DCCA I

FIG. 2.   Detrended canonical correspondence analysis (DCCA) ordination of species-by-environment variables for the Canelo Hills Ciénega (summer 1986). Species groups generally represent the following locations along the moisture gradient: I = dry, peripheral sites, II = wet, stream sites, and III = wet, ciénega sites. Names for species abbreviations are listed in Table 1.

trifida dominated the periphery that was characterized by a lack of standing water, dry soils, and no canopy cover.

Species used in all DCCA and DCA analyses for both ciénegas are listed in Table 1.

DISCUSSION

The floristic composition of graminoid and herbaceous species at the Babocomari Ciénega and the Canelo Hills Ciénega is similar to that found in other ciénegas in southeastern Arizona (Marrs-Smith 1980; Yatskievych and Jenkins 1981). Of the 135 species collected in 1985 at Babocomari Ciénega and the Canelo Hills Ciénega, many have been introduced from Eurasia or from range extensions north from Mexico (Correll and Correll 1975). Because no pristine ciénegas

TABLE 1. HERBACEOUS AND GRAMINOID PLANT SPECIES USED IN DETRENDED CANON-
ICAL CORRESPONDENCE ANALYSIS AND DETRENDED CORRESPONDENCE ANALYSIS FROM
THE BABOCOMARI CIÉNEGA AND THE CANELO HILLS CIÉNEGA.

Species	Abbreviations used in Figures 1 and 2
Agropyron trachycalum (Link.) Malte.	Agr tra
Ambrosia psilostachya DC.	Amb psi
Ambrosia trifida L.	Amb tri
Anemopsis californica (Nutt.) H. & A.	Ane cal
Apocynum suksdorfii Greene.	Apo suk
Berula erecta (Huds.) Coville.	Ber erc
Carex lanuginosa Michx.	Car lan
Carex praegracilis W. Boott.	Car pra
Cynodon dactylon (L.) Pers.	Cyn dac
Eleocharis caribaea (Rottb.) Blake.	Ele car
Eleocharis macrostachya Britt.	Ele mac
Eleocharis parishii Britt.	Ele par
Equisetum hiemale L.	Equ hie
Hymenothrix wislizenii Gray.	Hym wiz
Juncus balticus Willd.	Jun bal
Persicaria fusiforme Greene.	Per fus
Polypogon interruptus H.B.K.	Pol int
Medicago lupulina L.	Med lup
Mentha arvensis L.	Men arv
Mimulus glabratus H.B.K.	Mim gla
Muhlenbergia asperifolia (Nees & Mey) Parodi.	Muh asp
Muhlenbergia rigens Torr.	Muh rig
Paspalum distichum L.	Pas dis
Ranunculus macranthus Scheele.	Ran mac
Rorippa nasturtium-aquaticum (L.) Schinz & Thell.	Ror nas
Scirpus americanus Pers.	Sci amr
Sisyrinchium demissum Greene.	Sis des
Sorghum halpense (L.) Pers.	Sor hal
Sporobolus wrightii Munro ex Scribn.	Spo wri
Veronica americana (Raf.) Schwein.	Ver amr

exist, most extant ciénega vegetation reflects the local disturbance
history.

The Babocomari Ciénega and the Canelo Hills Ciénega have a
similar floristic composition because they have similar climatic re-
gimes, environmental conditions, and disturbance histories. How-
ever, of the 30 species included in the analysis, four were not shared
by both sites. Because of the large sample size, most species present
were likely found; the discrepancy may be due to unidentified site-
specific biotic and abiotic factors, such as interspecific competition
or variation in soil nutrient concentrations.

Differences may also be attributed to subtleties in the local wa-
tershed hydrology; the Canelo Hills Ciénega is located in a much
smaller, narrower basin with steeper slopes than the Babocomari
Ciénega. In addition, soil erosion was probably greater at the Canelo

Hills Ciénega than at the Babocomari Ciénega because the dam was installed 30 years later. It has been shown that ciénegas without manmade dams have either been lost entirely due to soil erosion or have a limited flora that is typically associated with grasslands, not ciénegas (Hendrickson and Minckley 1985; Marrs-Smith 1980).

The high eigenvalues (e > 0.50) for the first and second axes at the Babocomari Ciénega and the Canelo Hills Ciénega suggest that the chosen environmental variables are sufficient to explain most of the variation in species composition and distribution (Jongman et al. 1987). However, the eigenvalues at the Canelo Hills Ciénega are lower than for Babocomari Ciénega and this may reflect the fact that the sampling scheme was chosen based on a reconnaissance of Babocomari Ciénega. Also, inclusion of variables that more accurately reflect the grazing or flooding disturbance regime, such as clipped grasses or soil erosion, might increase the amount of variation explained by the environmental variables.

Finally, differences between the Babocomari Ciénega and the Canelo Hills Ciénega plant distributions and species composition may be due to recent changes in land use practices, specifically grazing by domestic cattle. A rare orchid, *Spiranthes graminea* Lindl., that is flourishing at Babocomari Ciénega, has gradually been replaced by invading grasses at the Canelo Hills Ciénega. Managers at the Nature Conservancy Preserve surmise that the removal of domestic cattle from the Canelo Hills Ciénega may be indirectly responsible for the demise of *S. graminea* (Campbell and Wiley pers. comm.). It is likely that cattle grazing reduces the competition for space or nutrients. While the Canelo Hills Ciénega has not been grazed for 20 years, in the early 1960's it was grazed until nothing remained but cracked, dry soil (Mr. Bud Ewing pers. comm.). On the other hand, the Babocomari Ciénega has been continuously grazed since at least the early 1930's. Because the Babocomari Ciénega is grazed, the invasion of *Juniperus deppeana* Steud. is restricted to areas unaccessible to cattle, whereas at the Canelo Hills Ciénega its presence may be due to a recent invasion following the removal of grazing pressures (Gawith 1987).

In conclusion, three similar species groups, including a stream group, a ciénega group and a grassland peripheral group, have been identified at the Babocomari Ciénega and the Canelo Hills Ciénega. These results establish a baseline for future studies that could focus on the abiotic and biotic interactions that influence the dynamic ecology of plant species that are unique to ciénega ecosystems of the southwestern United States.

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